Chapter 3: Framing the Decision Problem

3.1 Decision Framing

This chapter describes the development of the decision frames for the project. A decision frame specifies the decision maker(s), the decision alternatives, and the decision objectives. For decision problems with multiple stakeholders, it is important to involve the stakeholders in the development of the decision frames.

This project, as other EMF projects funded by the California Department of Health Services, was monitored and reviewed by a Stakeholder Advisory Consultants (SAC). This group had about 11 members, including representatives of the major investor-owned and municipal utilities in California, the unions, health organizations, environmental groups, residents living near electric power lines, rate payer advocates, and others. The SAC participated in the development of the decision frames in several ways.

The original decision frame, described in a request for proposal issued by the CDHS with review of the SAC, was very general. It suggested that the analysis was to support many different decision-makers, including regulators, the utilities, and environmental and residents' groups. The request for proposal suggested exploring a variety of alternatives for reducing EMFs, including standard setting, engineering fixes, and land use restrictions. Regarding objectives, the request for proposal suggested that the analysis should consider a broad range of concerns including, health, cost, property values, environmental justice, and others.

Framing a more specific decision problem within this general framework consisted primarily of narrowing down the problem to a specific set of decisions. This process was complicated by several factors. First, there are many levels of decisions about EMFs. At the national level, research agencies have to make decisions about the appropriate levels of funding for EMF research projects. At the state level, public utilities commissions may consider setting standards to reduce EMF exposure. At a regional level, utilities need to make decisions about siting and engineering improvements of the electric power grid. At the local level, city councils make decisions about setback regulations, undergrounding policies, and other ordinances. At the individual level, families make decisions about where to live and how much to pay for protection from this potential hazard. To complicate matters more, there are at least four sources of EMFs in the electric power grid: transmission lines, distribution lines, substations, and home grounding systems. Each of these involves special decision alternatives and objectives.

To develop more specific decision frames, we proposed to split the decision problem by the four sources of EMFs and whether the sources were existing or new. This led to eight possible "modules" (see Table 3.1). This augmentation of the problem helped somewhat, but it still required definitions of decision-makers, decision alternatives, and decision objectives for each of the cells in Table 3.1.

Table 3.1: EMF Sources in the Electric Power Grid

Grid Component	Existing	New
Transmission Lines		
Distribution Lines		
Substations		
Home Grounding Systems		

To better define the decision frames, four workshops were held in January 1997, three with potential decision-makers and one with other stakeholder groups. Representatives of the major regional California utilities, state regulators, and smaller municipal utilities participated in the first three workshops. Citizens concerned with powerlines, ratepayer representatives, union representatives, and individuals concerned with health risks participated in the fourth workshop.

For each cell in Table 3.1, the following questions were raised in each workshop:

1. Who can make decisions about the situation described in Table 3.1?
2. Who are the main stakeholders and those affected by the decision?
3. What are the major classes of alternatives that the decision-makers can control?
4. What are the criteria for evaluating the decision alternatives?

The workshop produced four sets of results. Table 3.2 shows a list of decision-makers; Table 3.3 shows several classes of stakeholders; Table 3.4 shows a list of decision alternatives; and Table 3.5 shows a set of high-level decision criteria. These tables provided the master-lists, which we used to produce specific decision frames for the cells in Table 3.1.

Table 3.6 provides an example of a more specific decision frame for existing transmission lines. In particular, this case examined alternative ways to reduce EMF exposure for an existing transmission line located on a clear right-of-way through a 15-mile stretch of fairly dense residential housing. Once a decision is framed at such a specific level, it is also possible to define the decision-makers, stakeholders, alternatives and objectives in more detail. Regarding alternatives, there are several specific engineering options to reduce EMF exposure, either by changing the phasing of the currents in the existing lines, by changing the line configuration, by increasing the height of utility poles or towers, by changing the load on the line, or by undergrounding the line. Undergrounding is the only alternative that virtually eliminated EMF exposure in this case, but it does so at a very high cost. All other engineering options reduce EMF exposure by between 10% and 80%. Non-engineering options include increasing the right-of-way (practical only where no current houses exist) and restricting the use of the right-of-way (e.g., by fencing it in to avoid public use). While there are many more objectives for this particular decision, Table 3.6 lists only the ones that differentiate among the alternatives.

Table 3.2: Decision-Makers Involved in EMF Decisions

Federal	Federal Energy Regulatory Commission Environmental Protection Agency Occupational Safety and Health Administration Consumer Products Safety Commission Bureau of Land Management
State	California State Legislature California Public Utilities Commission California Independent System Operator Building Standards Commission
Regional	Councils of Government Regional Planning Committees Investor-Owned Utilities
Local	City Councils City Planning Departments Municipal Utilities

Table 3.3: Classes of Stakeholders for Reducing EMF Exposure

Stakeholder	Major Concerns	Examples
Utilities	Service Reliability Cost	Pacific Gas and Electric Southern California Edison San Diego Gas and Electric Los Angeles Water and Power
Regulators	Safety Health Reliability Cost	California Public Utilities Commision California Energy Commission California EPA California Independent Systems Op. City Councils
Rate-Payers	Utility Rates	Ratepayers' Association
Residents	EMF-Exposure Property Values Rent	Citizens Concerned about EMF Undergrounders
Environmental & Advocacy Groups	Environmental Impacts Health	Sierra Club Environmental Defense Fund National Brain Tumor Foundation Parent-Teacher Organizations
Unions	Worker Safety Worker Health Salaries	Electric Utilities Union
Research Agencies	EMF Research Base Competing Research	Electric Power Res. Institute Nat'l Institute for Env. Health Science U.S. EPA Cal. Energy Commission Cal. Dept. of Health Services
Professional Organizations	Enhance Profession	Bioelectromagnetic Society Physics Society American Industrial Health Council

Table 3.4: Classes of Alternatives for Reducing EMF Exposure

	Existing	New
Transmission Lines	Line Configuration Phasing Undergrounding Land Use Restrictions Standards Warning Labels	Route Selection Line Configuration Undergrounding Land Use Restrictions Standards
Distribution Lines	Balance Load Undergrounding Raise Pole Height	Route Selection Pole and Line Configuration Undergrouding
Substations	Re-locate	Site Selection
Grounding Systems	Improve Net Return Insulate Water Pipe	Location of Service Drop

Table 3.5: Classes of Criteria for EMF Decisions

- EMF-Related Health Risks
- Accidents due to EMF Mitigation
- Life-Cycle Cost
- Property Impacts
- Service Reliability
- Impact on the Environment
- Socioeconomic Impacts
- Implementation Concerns
- Equity and Environmental Justice

Table 3.6: Specific Decision Frame for Existing Transmission Lines

Decision Maker(s)	California Public Utilities Commission Investor-Owned Utilities Municipal Utilities
Stakeholders	Residents Living Near Transmission Lines Children in Schools Near Transmission Lines Workers with Jobs Near Transmission Lines Ratepayers Utility Workers
Alternatives	Re-Phasing Split-Phasing Undergrounding Increase Pole or Tower Height Decrease Line Sag Reduce Load Increase Right-of-Way (ROW) Restrict Activities in ROW
Objectives	Reduce EMF Related Health Risks Leukemia Brain Cancer Breast Cancer Alzheimer's Disease Reduce Costs Total Project Costs Operation and Maintenance Cost Conductor Losses Increase Service Reliability Reduce Outages Reduce Property Impacts Reduce Impacts on Property Values

3.2 Values and Objectives

Values are the principles that guide people's decisions. They are either expressed as decision imperatives ("thou shalt not kill"), desired end states ("peace"), or preferred directions ("increase wealth"). Values help people to manage their life to produce consequences that they like. Without values, people would have to re-think every individual decision and examine its specific consequences and how they would feel about them (see Keeney, 1992).

When people express a preference or justify an action, they typically refer to their values. For example, when asked, why they oppose the construction of a new powerline near their home, residents may state that they value their children's health, the environment, their view and their properties more than the need for improved electricity service. Values often come in packages like "religious values," "family values," or "environmental values."

Objectives are specific expressions of values. An objective involves an object of value and a direction of preference (Keeney, 1992). For example, an object of value may be the health of a person, and the direction of preference may be to improve the person's health. Other examples are "to increase wealth" and "to improve one's psychological well-being."

It is useful to distinguish between means, ends, and process objectives. Ends objectives are the ones that a decision-maker truly cares about. For example, in medical decisions, patients typically care about prolonging the length and quality of their lives. Ends objectives can be discovered with a simple test: Ask, why a person cares about a stated objective. If the answer is, "that is self evident," it is an ends objective. If the answer is, "because achieving this objectives contributes to achieving another objective," it is a means objective. For example, a woman choosing a new car may state that one of her objectives is the size of the car. When asked why, she may state that she likes the protection of a large car for safety. When asked why, she may say that a safer car reduces the risks of deaths or injuries to her family and herself. When asked why this is important, she probably will just stare at you – it's a self-evident ends objective. We also refer to ends objectives as "decision criteria."

Means objectives are important, because they contribute to achieving ends objectives. In the car example, the size of the car is a means to reducing risks of deaths and injuries. Reducing air pollution is a means to reduce the health impacts of people exposed to it. Even money is a means – to health, to enjoyment of life, and to helping others enjoy life.

Means and ends objectives can be used to evaluate decision alternatives. Process objectives, in contrast, do not differentiate among the alternatives, but they differentiate among decision processes. Examples of process objectives are "fairness," "public involvement," and "accountability." In all examples, it is not the alternatives that are

"fair," "involve the public," or "accountable," but the decision process that is used to select from among them.

Means and ends objectives can be represented by a means-ends network (Keeney, 1992) or by an influence diagram (Clemen, 1990). Ends objectives can be represented as a hierarchy or tree (Keeney, 1992; von Winterfeldt and Edwards, 1986). The purposes of creating means-ends networks are to clearly distinguish between means and ends and to clarify their causal relationships. An arrow in a means-ends network means "to cause a change" or "to influence." Means-ends networks are also useful to build models that relate the alternatives to value-relevant consequences.

Figure 3.1 shows a simple means-ends network for an EMF decision. In this diagram, decisions are shown as boxes, means objectives as ellipses, and ends objectivs as rounded boxes. A question mark on top of the arrow connecting "EMF Exposure" and "Health Effects" indicates that this relationship is uncertain.

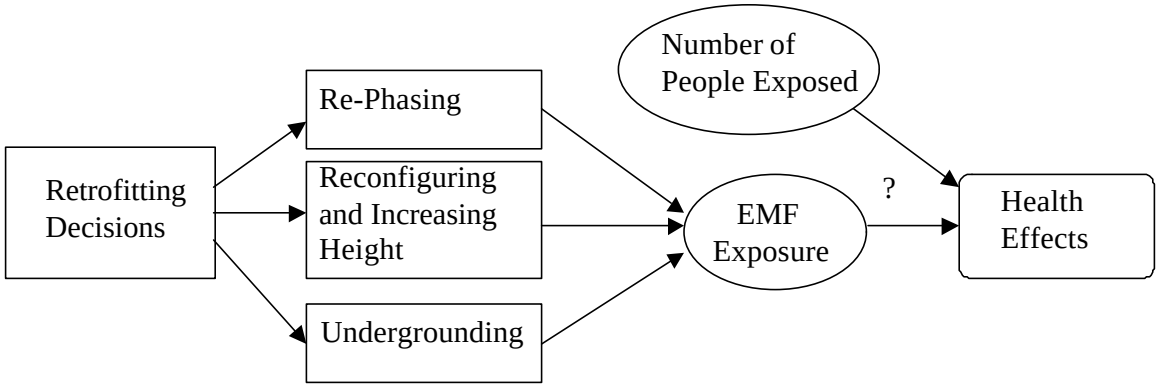

Figure 3.1: Example Means-Ends Network for EMF Decisions

Figure 3.2 shows a segment of a tree of ends objectives for the transmission line retrofitting decision. This tree defines the general areas of concern (at the root of the tree) and specifies details of these concerns by sub-objectives (as the branches of the tree). The arrow in an objectives tree means "is specified by." The figure shows the potential health effects that have been most frequently associated with EMF exposure: brain cancer, breast cancer, leukemia, and Alzheimer's disease. The project studied brain cancer and leukemia separately for adults and children under 14 years of age. Breast cancer was studied for adult women only. Alzheimer's disease was studied for people over the age of 65 only. The project included an analysis of both mortality and morbidity for these health endpoints. The models were flexible enough to include additional health endpoints specified by the user.

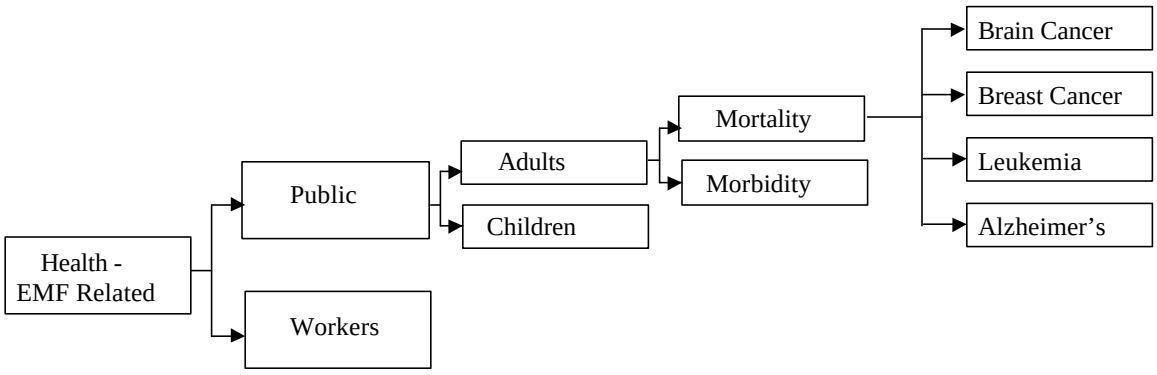

Figure 3.2: A Segment of an Ends Objectives Tree for an EMF Decision

A significant part of the EMF workshops described in the decision framing part of this chapter was concerned with identifying objectives for four stakeholder groups: utilities, state regulators, local governments, and residents/environmental groups opposed to EMF exposure. Tables 3.7-10 show the set of objectives generated in these workshops for the four stakeholder groups.

The Stakeholder Advisory Consultants had an opportunity to review these sets of objectives, but few changes were made as a result of this review. However, as the objectives were developed in more detail, some stakeholders began to make additions to the objectives. The utilities added objectives related to the direct cost of transmission and distribution and asked for a specific cost breakdown. The residents added objectives related to the social costs of overhead transmission lines, such as air pollution, property damage due to fires, and loss of trees.

Table 3.11 shows the combined list of ends objectives used in this project and the measures that were used to estimate how well the alternatives performed. We will often refer to these ends objectives and their measures as "decision criteria." Table 3.12 shows the detail of the health objectives, which were split into mortality and morbidity and by population group (general public, children, or workers). Altogether there are 39 criteria, 15 related to EMF health concerns.

Table 3.7: Objectives of the Utilities

Ends Objectives	**Means Objectives**
Health and Safety Public Health (EMF) Worker Health (EMF) Indirect Risks Due to Routing Due to Reduced Reliability Environment Aesthetics Cost Land Construction Maintenance Local Development Growth Infrastructure Reliability Outages Indirect Impacts of Outages Cost Lost Revenue Possible Damages Environmental Impacts Crime, Public Safety Property Values Due to EMF Due to Other Causes Planning and Regulatory Concerns Adaptability to Deregulation Impact on Long-Term Local Planning Compliance with Regulations	Means Affecting Aesthetics Routing of Powerlines Reliability Pole and Tower Height Number and Type of Poles and Towers Number and Configuration of Lines Means Affecting Ease and Cost of Maintenance Frequency of Maintenance Ease of Access Time for Maintenance Training of Crew Means Affecting Outages Number of Outages Duration of Outages Means Affecting Property Values Service Reliability Cost of Service Power Availability **Process Objectives** Public Acceptance Adaptability to Deregulation

Table 3.8: Objectives of the State Regulators

Ends Objectives	**Means Objectives**
Health Impacts EMF Risks to the Public EMF Risks to Workers Risks from EMF Mitigation Equity and Fairness Cost Equity Health Equity Property Values Equity Economic Impacts Growth Development Reliability of Electrical Service Environmental Impacts Aesthetics Noise and Disruption Flora and Fauna Costs Construction Operation and Maintenance	Implementation Concerns Practicality Timeliness Liability **Process Objectives** Implementation Concerns Political Feasibility Political Support Value of Information Validity of Information Clarity of Information Acceptance of Information

Table 3.9: Objectives of Local Governments

Ends Objectives	**Means Objectives**
EMF Risks Public Workers Property Values Liability Compensation Punitive Damages Maintenance and Reliability Impacts on Local Development Growth Blight Other Social Consequences Environment Justice and Fairness - Outcomes	Means to Liability Hassles Other Means Value Added to Other Alternatives Compatibility with Other Alternatives
	Process Objectives
	Public Perceptions and Reactions Decision Process Concerns Timeliness Defensibility Justice and Fairness - Process Process Fairness Environmental Justice

Table 3.10: Objectives of Residents and Environmental Groups

Ends Objectives	**Means Objectives**
Public Health Risks Leukemia Brain Cancer Breast Cancer Electrocutions Other Health Endpoints Worker Health Risks From EMF Exposure From Other Causes Distrubution of Risks Children vs. Adults Voluntary vs. Involuntary Minorities vs. Others Across Socioecon. Groups Property Value Loss Visual Impacts and Aesthetics Justice and Fairness - Outcomes Fair Distribution of Costs Fair Distribution of Risks Costs Direct Costs Social Costs Due to EMF On Housing Due to Property Devaluation Service Reliability Outages Consistency with Existing Regulations	Means Affecting Property Values Stigmatization Means Affecting Cost Impacts of Risk Avoidance Impacts of Liability and Law Suits Means Affecting Outages Storm Hazards Fires **Process Objectives** EMF Management Flexibility Practicality Credibility of Information Avoid "Alarming" People Local Autonomy Impacts on Property Rights Local Control Impacts on Land Use

Table 3.11: Combined List of Ends Objectives and Measures
(Socioeconomic impacts and implementation concerns were considered only in the state-wide roll-up, not in the ANALYTICA® models)

Criteria	Measures
Health Effects - EMF	
Leukemia	
Brain Cancer	For cancer incidence: Number of cases
Breast Cancer	For fatal cancer: Life-years lost
Alzheimer's Disease	For Alzheimer's: Number of cases
Health Effects - Accidents	
Fires	
Pole Collisions	For fatalities: Life-years lost
Electrocutions	For injuries: Number of cases
Construction	
Cost	
Total Project Cost	1998 dollars
O&M	1998 dollars
Power Losses	1998 dollars
Service Reliability	
Contingencies	Number of contingency hours
Customer Interruptions	Number of person-hours of interruption
Property Impacts	
Property Values	1998 dollar change in property values
Fire Losses	1998 dollars
Pole Collision Losses	1998 dollars
Environmental Impacts	
Aesthetics	Aesthetics point scale
Tree Losses	Number of trees lost
Air Pollution	Percent change of fossil fuel generation
Noise and Disruption	Person-days of noise and disruption
Socioeconomic Impact	
Gross Regional Product	1998 dollars
Employment	Percent change in employment
Implementation Concerns	
Equity and Env. Justice	Qualitative judgment
Practicality	Qualitative judgment
Compliance	Qualitative judgment

Table 3.12: Health Ends Objectives with Detail

(The italicized items indicate where criteria are defined with measures)

Health Ends Objectives	
EMF	**Accidents**
Leukemia Mortality Public *Children* *Adults* *Workers* Morbidity Public *Children* *Adults* *Workers* **Brain Cancer** Mortality Public *Children* *Adults* *Workers* Morbidity Public *Children* *Adults* *Workers* Breast Cancer *Mortality (Adult Female)* *Morbidity (Adult Female)* Alzheimer's Disease *Morbidity (over 65 only)*	**Fires** *Public Fatalities* *Public Injuries* **Pole Collisions** *Public Fatalities* *Public Injuries* **Electrocutions** *Public Fatalities* *Worker Fatalities* **Construction** *Worker Fatalities* *Worker Injuries*

3.3 Modules and Scenarios Selected for Analysis

Based on the decision-maker and stakeholder workshops, we selected the following policy analysis modules for further analysis:

1. retrofitting existing transmission lines,
2. retrofitting existing distribution lines,
3. siting and configuring new transmission lines,
4. improving home grounding systems.

For each module we developed two or three scenarios that describe fairly specific circumstances for decision making. These scenarios are described below, followed (in brackets) by the ANALYTICA® model name.

1. Retrofitting existing transmission lines:

    a. Retrofitting a 69 kV single circuit line that connects two substations (rated ampacity of 600 A). The line is located on poles on one side of a road. The distance between the two substations is 15 miles with variable population densities and home values. The line passes by a school with 1,000 students. (TR-69.ana)

    b. Retrofitting a 115 kV double circuit line that connects two substations (rated ampacity of 600 A). The line is located on a lattice structure on a cleared right-of-of way, with a fifty-foot distance to the property lines of the adjacent houses. The distance between the two substations is 15 miles with variable population densities and home values. The line passes by a school with 1,000 students. (TR-155.ana)

    c. Retrofitting a 230 kV bulk power transport line that connects a power plant with a substation in a suburban area. This double circuit line is on a cleared right-of way of 120 feet width and it is 50 miles long. Its rated ampacity is 1,000 A. The land use is mixed with some lower density residential areas. (TR-230.ana)

2. Siting and configuring new transmission lines:

    a. A new 115 kV transmission line is built to connect two points, A and B. Its rated ampacity is 1000 A. The shortest distance between the substations passes through a relatively densely populated area and goes directly by a school. Therefore, two alternate routes are considered: one that will merely bypass the school, and another much longer route that bypasses both the school and the densely populated area. (TN-115-A.ana)

    b. A new 115kV transmission line is built to connect two points, A and B. The line is 10.5 miles long and passes through mixed urban/suburban areas. No

routing alternatives are considered, but the right-of-way is either set at 100 feet or 200 feet width. (TN-115-B.ana)

c. A new transmission line is built to connect two points, A and B with an existing 33 kV Delta configured distribution line in place. The line has a rated ampacity of 1000 A. The line is 10.5 miles long and passes through mixed urban/suburban areas. This scenario I to examine the effects of underbuilt distributions lines. (TN-115-C.ana))

3. Retrofitting existing distribution lines:

a. A 12 kV three-wire distribution line is connected to a substation and terminates after 4 miles. The existing line is on a 40 ft. wooden post and runs on a street side in a suburban environment. (DR-A.ana)

b. A 21 kV four-wire distribution line is connected to a substation and terminates after 4 miles. The primary of the existing line is connected to the neutral. The line is on a 40 ft. wooden post on a street side in a suburban environment. (DR-B.ana)

4. Improving home grounding systems:

a. This is a single story home with water and electric utilities at opposite sides. The neutral is grounded to the water pipe, causing a net return current through the pipe. (HOME-A.ana)

b. This is a two-story home with water and electric utilities at opposite sides. The neutral is grounded to the water pipe, causing a net return current through the pipe. (HOME-B.ana)

For each module/scenario, we first examined all alternatives listed in Table 3.4 and screened them for practicality, feasibility, and compliance. For the powerline modules we used all criteria in Tables 3.11 and 3.12. For the home grounding scenarios, we only used the health and cost criteria. Chapter 8 will refer back to these modules and scenarios and describe in detail the ANALYTICA® models that we developed for them.